Utilizing MRail's vertical track defection measurements to identify and quantify the risk of soft spots in track for maintenance prioritization

FRA Track & Railroad Workplace Safety Symposium

April 6, 2022

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Topics to be Discussed

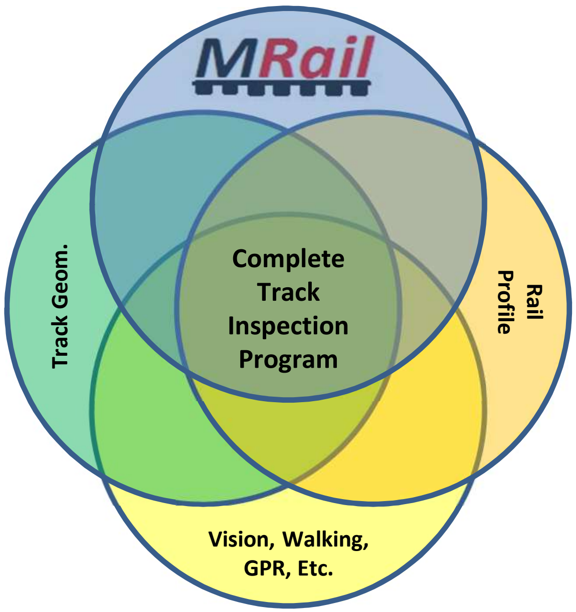
- Overview of *MRail* Vertical Track Defection Measurement System (VTDMS)
- Discuss Active FRA Project Goals
  - Improvements being made to *MRail* systems
  - Mudspot/soft spot risk model development
- Application of system and risk model to BPRR
  - Overview of BPRR
  - Track comparisons from inspection
  - Feedback from BPRR on how MRail data can guide maintenance
- Next steps

MRail System Overview

General Details About the MRail VTDMS

MRail System Details

Part of a complete track inspection program



- *MRail* can measure vertical rail deflection as the change in shape from unload to loaded rail surface
- *MRail* can report areas of track where track strength is lacking due to high vertical rail deflection
- *MRail* can help track the change in vertical rail deflection over time to expose areas of weakening track support

MRail should be seen as augmenting existing inspection processes

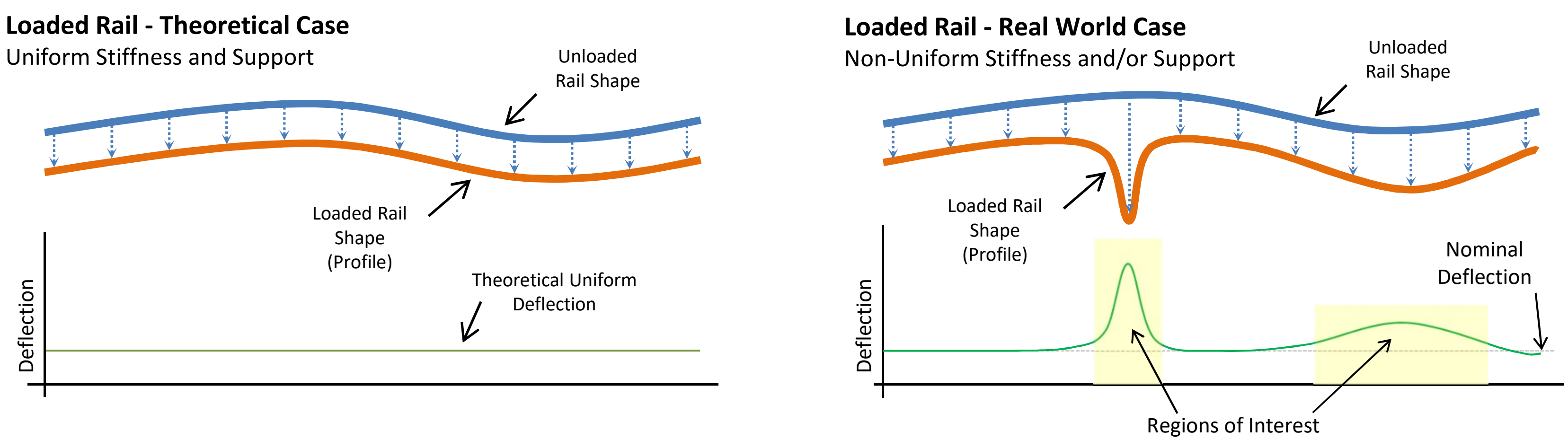
- *MRail* adds critical information on the track structure that is difficult and time consuming to measure using other techniques
- Adds information that track walkers and hy-rails cannot see easily

MRail System Details

What does *MRail* measure?

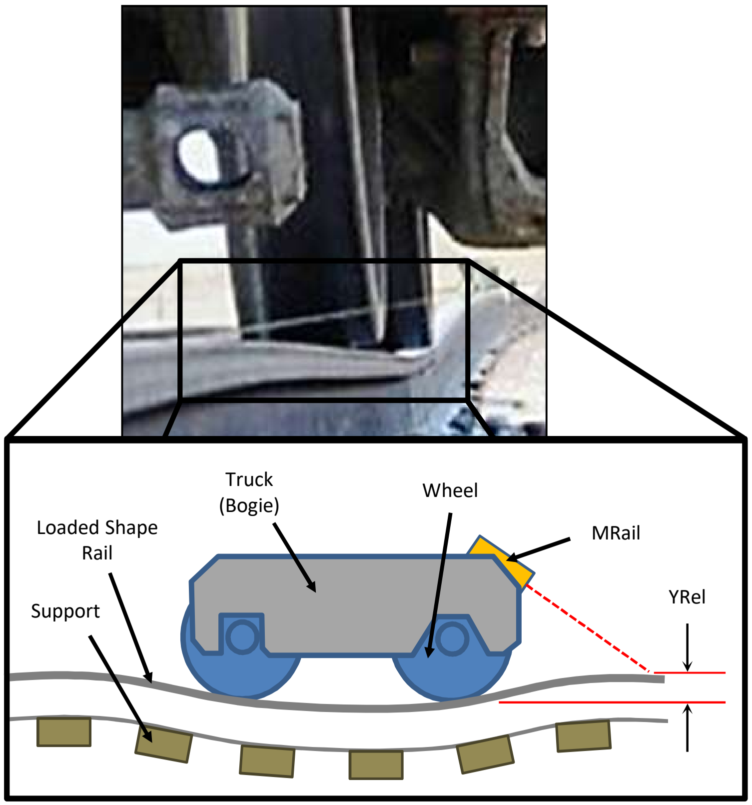
MRail measures and records the actual vertical difference (YRel) between the unloaded and loaded rail states

(Shown as the arrows in the below examples)



Effects of structural and/or support variations on rail deflection

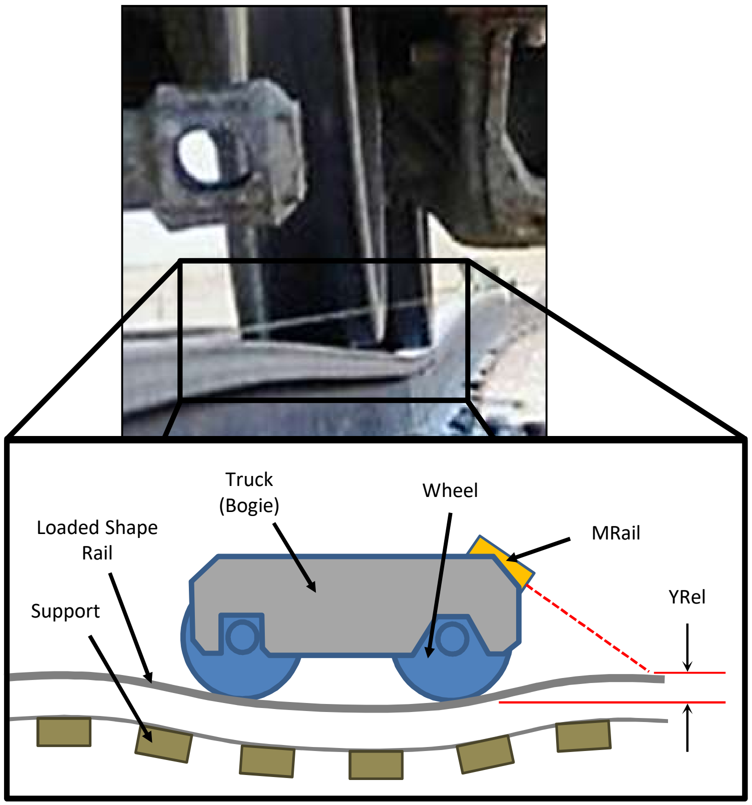
MRail System Details



Photographic and schematic representation of vertical rail deflection

- *MRail* measures the vertical difference between the loaded and unloaded rail shape
  - Measurement made relative to wheel/rail contact point
- Fully autonomous operation
  - Mounts on revenue car
  - Solar powered or powered by train consist
- Processed data can help prioritize and direct maintenance activity
  - Can correlate data with locations of track components
    - Culverts
    - Crossings
    - Bridges
    - Etc.

MRail System Details

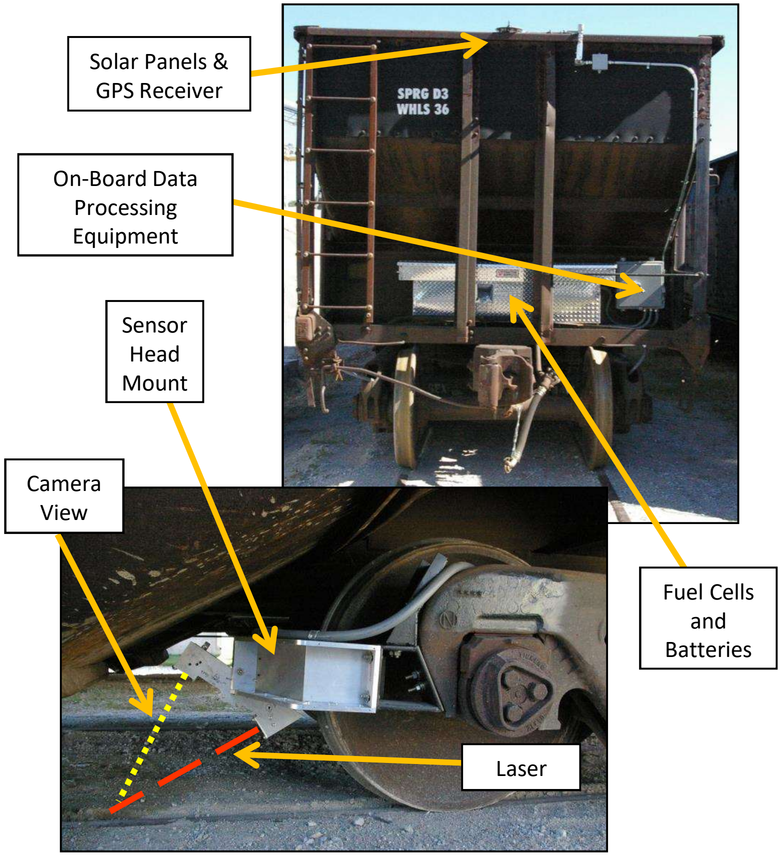


Photographic and schematic representation of vertical rail deflection

- Potential Identifiable Track Issues
  - Broken or weakening ties (sleepers)
  - Broken or weakening joints
  - Track structural support issues
    - Locations of weak or failing ballast
    - Locations of weak or failing sub-grade
    - Issues with bridge structures
    - Issues with pipes or culverts
  - Assign risk value to mud spots / soft spots

MRail System Details

System hardware – autonomous system installation



MRail mounted on a revenue rail car

MRail is an autonomous, compact, laser/camera based measurement system

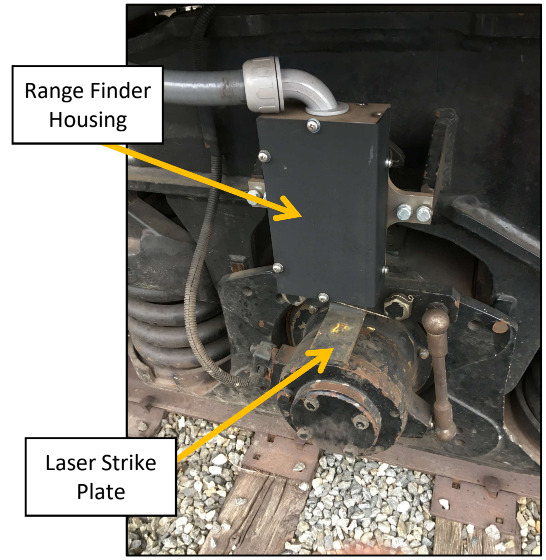
- Mounts on revenue generating car
  - Fully loaded cars give greatest results
- Laser/camera sensor head to capture coordinate data
  - Sensor head aimed 1.2m (4 ft) from nearest axle
- Uses solar panels with battery storage for power
- Computer system for data processing
- Data transmitted via cell modem to FTP site

MRail sensor head

MRail System Details

System hardware – FRA inspection vehicle integration

DOTX218



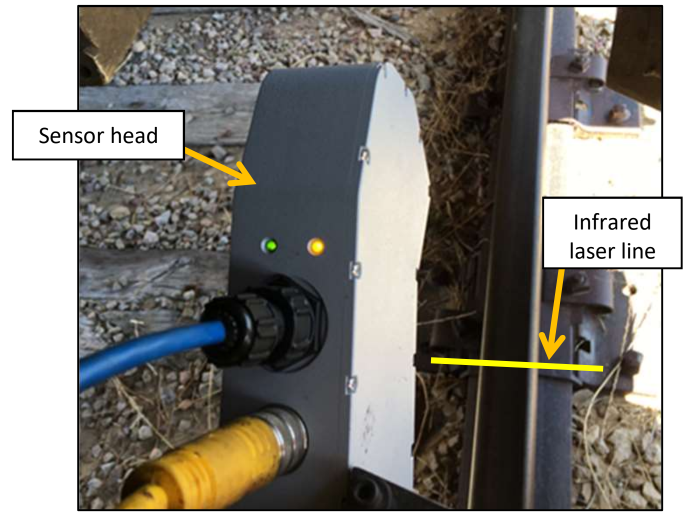
DOTX218 MRail range finder

- DOTX218 MRail system is a special case
  - DOTX218 has a secondary suspension
    - Laser range finders are used to identify the additional bogie movement caused by the suspension
  - DOTX218 MRail system is integrated into the car's master control software
    - Data capture is triggered by system
    - Data can be aligned with other measurement systems on vehicle
  - System is powered by the car's shore power system

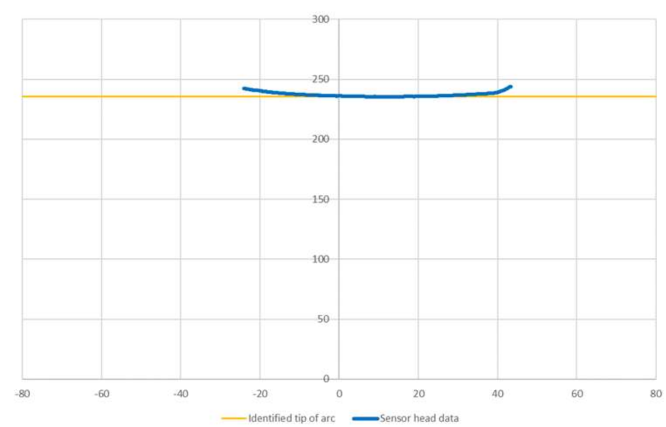
MRail System Details

Basis of measurement

- The *MRail* system functions by tracking the tip of an arc created
  - The arc is created by the line laser on the sensor head
  - The laser is applied to rail outside of the deflection wave
- As the nearest wheel depresses the rail, the position of the arc changes in the field of view
  - This varies based on the stiffness of the track/support
- The top of arc position is converted to YRel (rail deflect) via calibrated equations



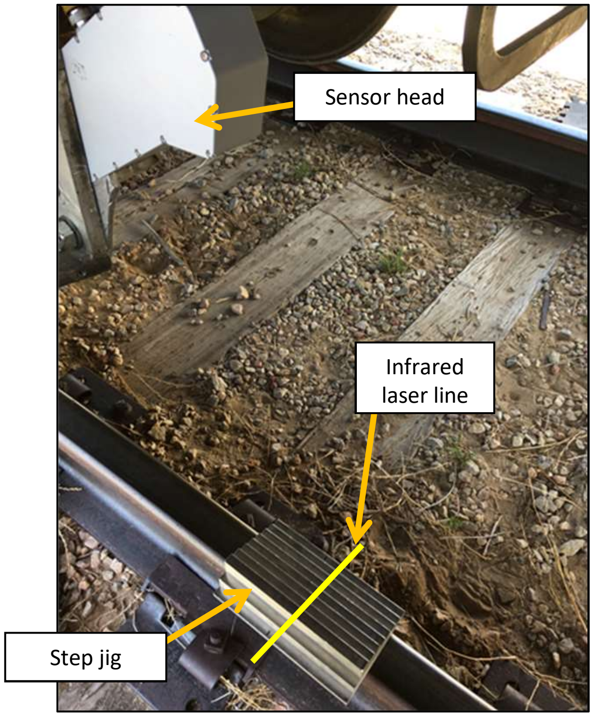
Sensor head with simulated laser line



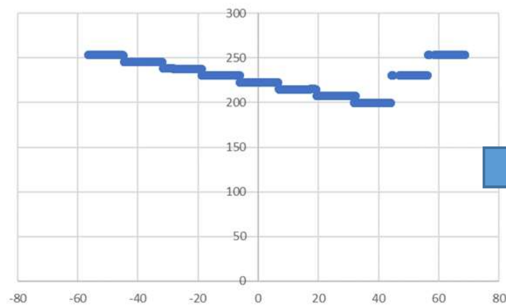
Captured sensor head data with top of arc position highlighted

MRail System Details

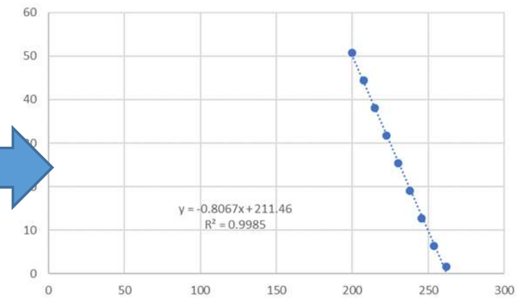
System calibration



Sensor head with step jig and simulated laser line



Step jig as seen by the sensor head



Plotted top of step pixels by step size

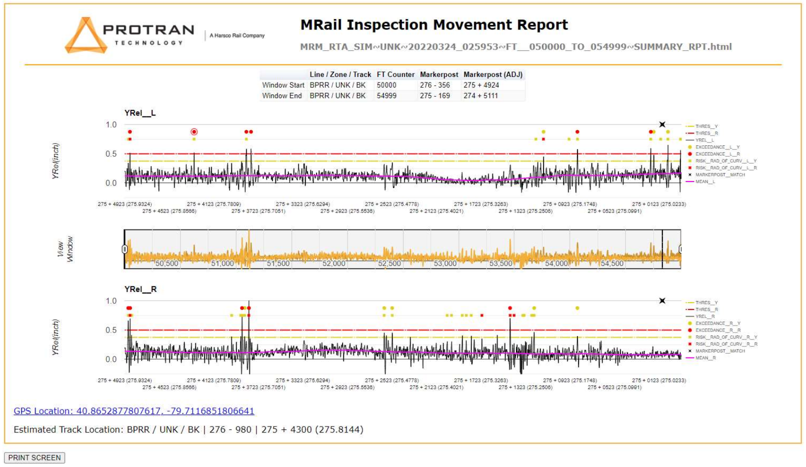
- System calibration is achieved via a two stage process
- Stage 1: Static Calibration
  - A step jig is used to associated field of view pixel location to a vertical measurement
  - The step jig's coordinates are captured
  - Each step height's pixel value is recorded
  - A plot is made and a line equation derived
    - Equation used to calculate initial YRel value
- Stage 2: Dynamic Calibration
  - The mean of the YRel signal of a measured length of track is offset to match the expected mean

Uses of *MRail* Output Data

Various Ways to use MRail Output Data

Standard *MRail* System Output

- Similar to other measurement systems, *MRail* outputs data in foot-by-foot measurements
- Standard *MRail* system outputs (after post-processing) include:
  - CSV of YRel data
  - Interactable strip charts
  - Exceedance reports
    - Locations where YRel was over a limit for a length of track



MRail strip chart output

Standard *MRail* System Output

Strip charts

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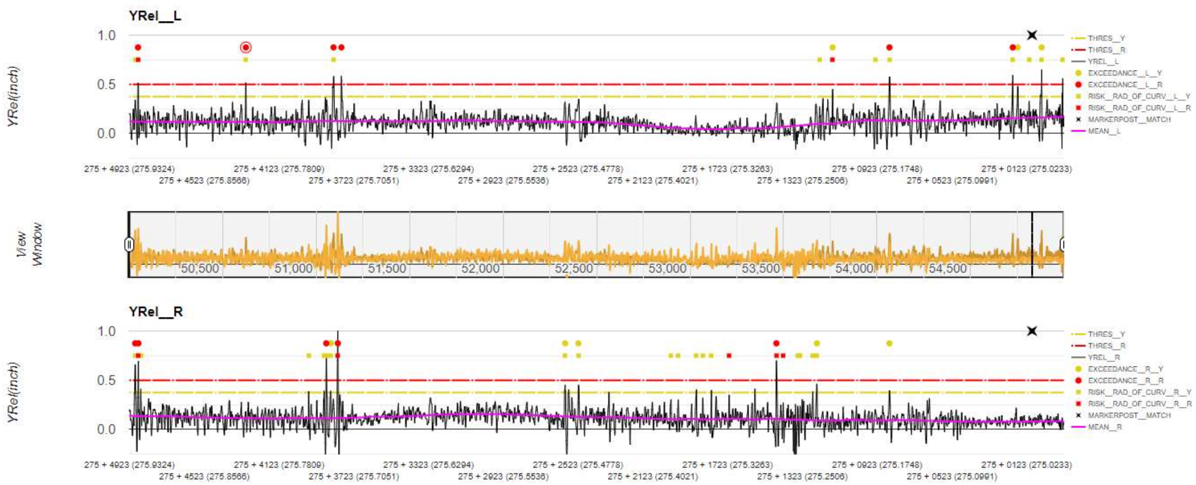
MRail Inspection Movement Report

MRM_RTA_SIM~UNK~20220324_025953~FT__050000_TO_054999~SUMMARY_RPT.html

	Line / Zone / Track	FT Counter	Markerpost	Markerpost (ADJ)
Window Start	BPRR / UNK / BK	50000	276 - 356	275 + 4924
Window End	BPRR / UNK / BK	54999	275 - 169	274 + 5111



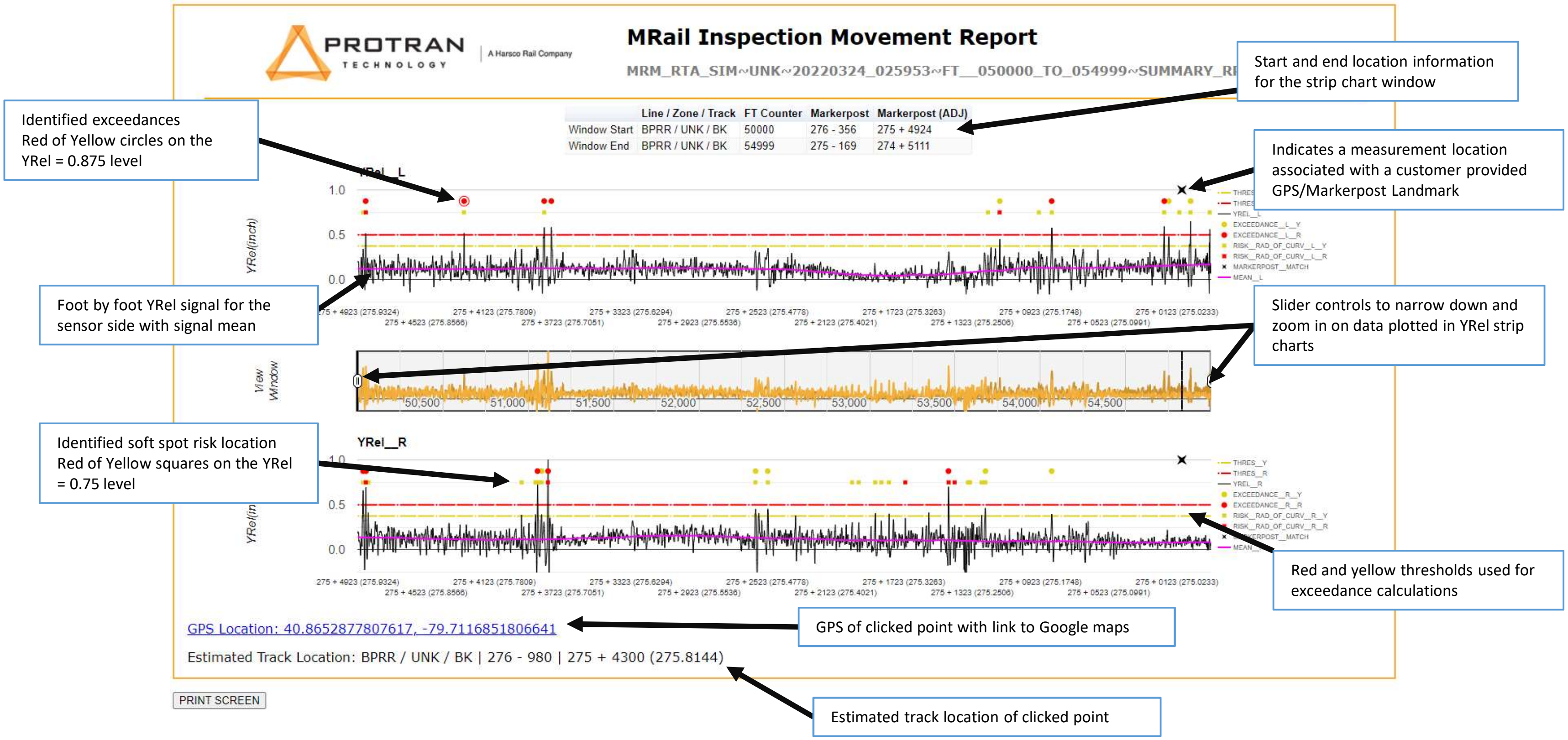
GPS Location: 40.8652877807617, -79.7116851806641

Estimated Track Location: BPRR / UNK / BK | 276 - 980 | 275 + 4300 (275.8144)

PRINT SCREEN

Standard *MRail* System Output

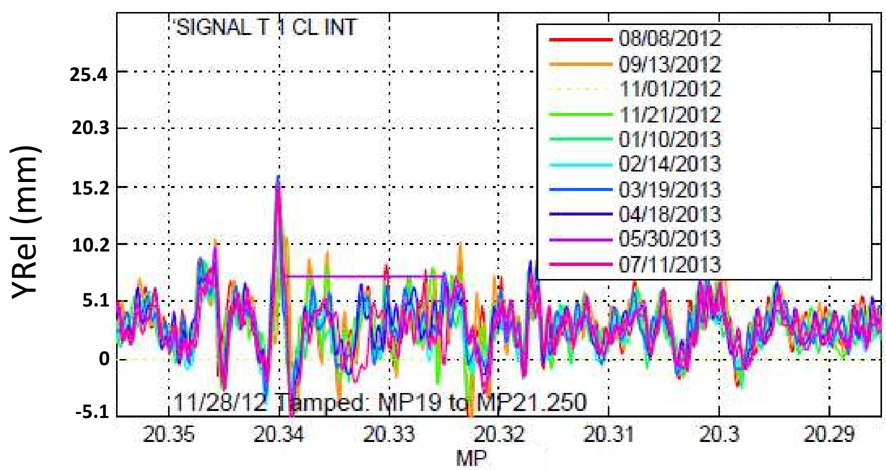
Strip charts

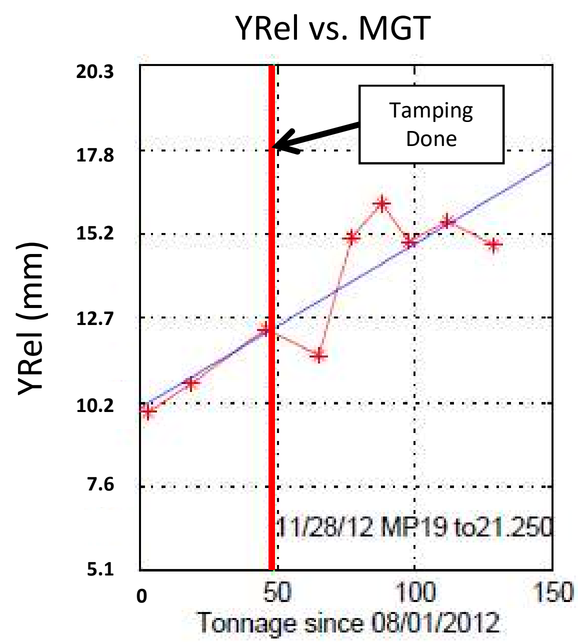


Potential Data Processing

Example of a degradation analysis

- Maximum region deflection was plotted by tonnage
  - Could look at average measurement in a region as well
- Historical trend analysis of data yields an expected deflection estimation of *worst actor* for the region

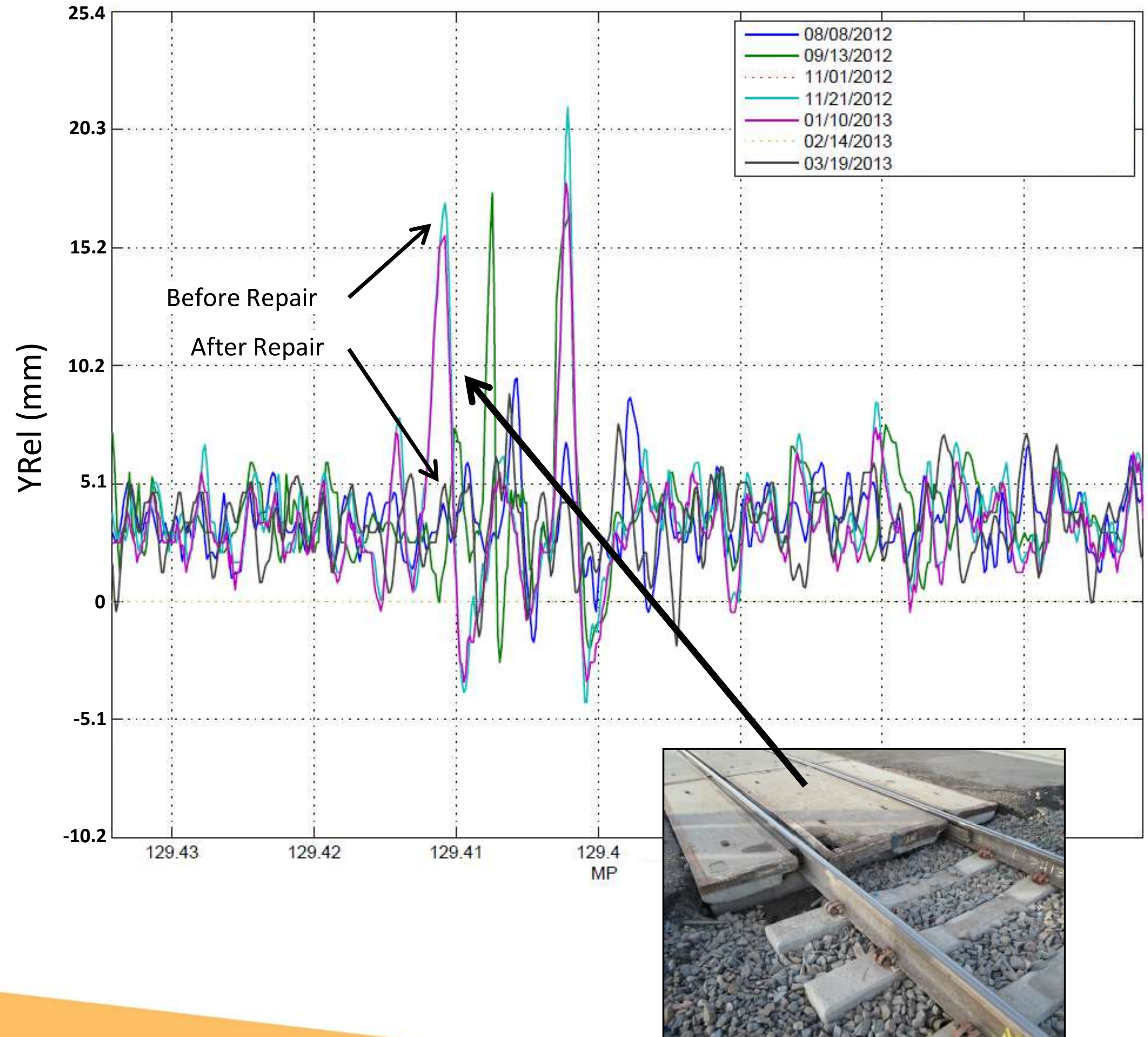




Potential Data Processing

Example of maintenance quality check

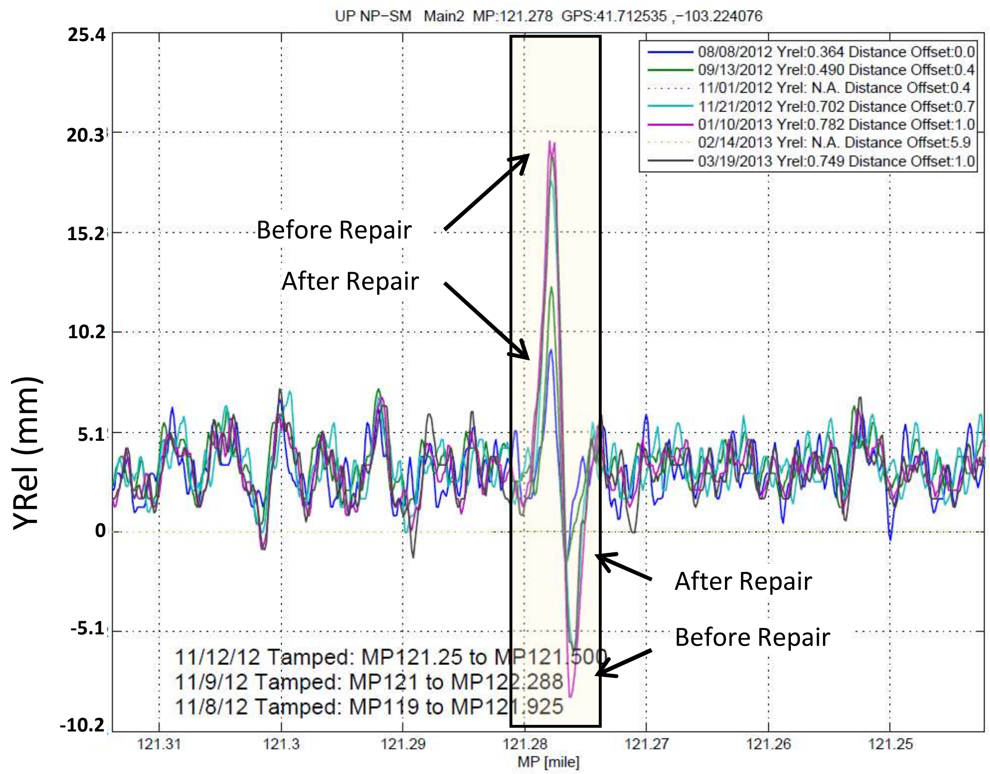
- *MRail* identified a region of track containing a crossing
- Inspectors found the crossing region needing repairs
- Repairs were made and *MRail* measured deflection decreased
- This location can be monitored over time to confirm repair addressed the underlying problem



Potential Data Processing

Example of an identified damaged culvert (pre and post repair)

- A culvert was identified by *MRail* for having high vertical rail deflection
- Tamping was repeatedly attempted to address deflection
  - No change in YRel



Culvert was repaired due to collapsed/broken support collar. Subsequent measurements confirmed successful repair

Comparison to Track Geometry

Why MRail and Track Geometry compliment each other

Comparison to Track Geometry

Where track geometry falls short

- Examples where track geometry will miss track issues but *MRail* will not
  - Soft in soft out support issues
    - Areas of track where low g-forces are experienced going from one support condition to another
    - The train is eased in and out of soft area of track
      - Continuous regions of soft ballast or sub-grade
      - Regions of continuous tie failures
  - Regions where point of deflection is higher than surroundings
    - When the track deflects, the high spot deflect in line with the surrounding rail
    - Track geometry would register no significant change in acceleration

Typical track geometry systems are inertial based. In order for a location to be flagged as an exception, <u>sufficient</u> accelerations (g-forces) need to be measured.

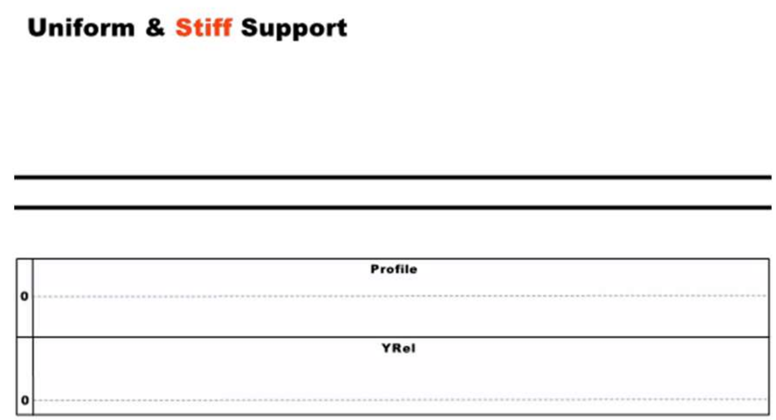
Comparison to Track Geometry

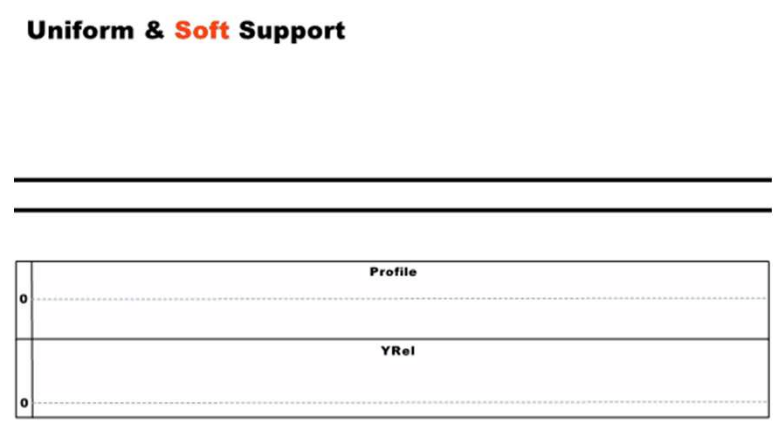
Where track geometry falls short

Some discrete track support issues can be seen via track geometry; however, a large amount of support issues such as continuous soft support cannot

In this example:

- Track profile is constant at zero
  - Since support does not vary, profile will not vary
- Deflection (YRel) changes
  - The magnitude of YRel is inversely proportional to support strength
    - Stronger the support, lower the deflection
    - Softer the support, greater the deflection

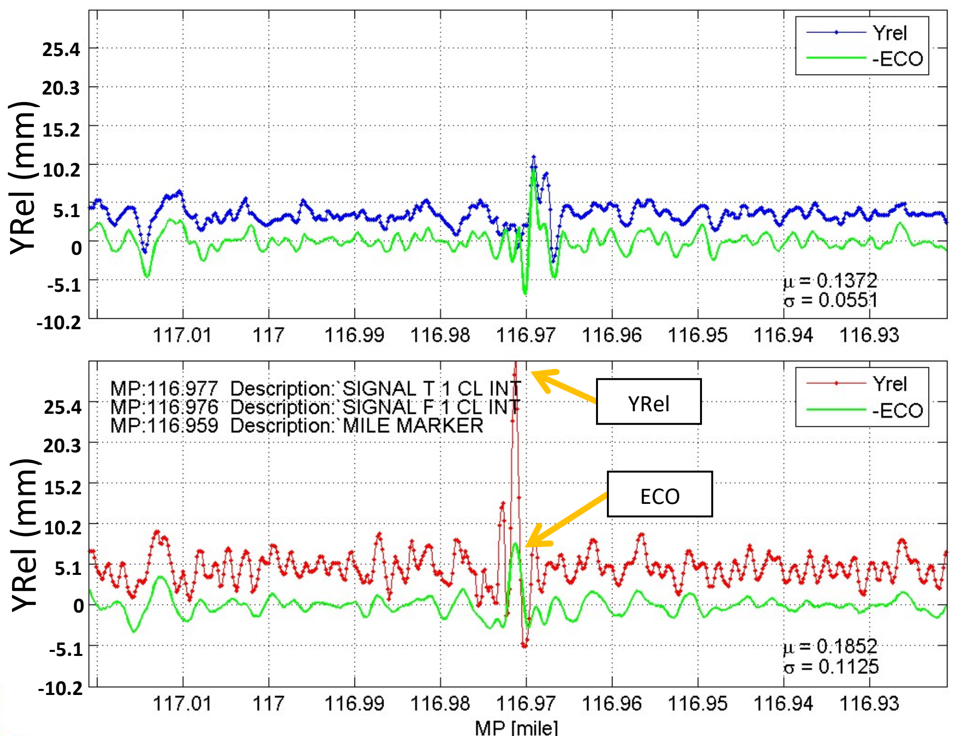


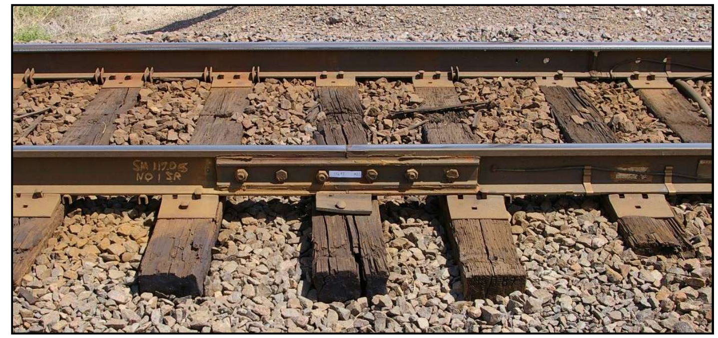


Comparison to Track Geometry

Where track geometry falls short – example

Although track geometry (ECO) shows a small deviation from the norm, it was insufficient to cause concern due to smooth transition. *MRail* (YRel) was able to quantify the severity of the structural issue.





Video of broken tie deflection smoothing rail profile

Active FRA Project

Discussion of the Current FRA Project and its Goals

Primary Tasks

- Currently have an active 12 month project with the FRA to continue to develop the system and its output
  - Period of Performance: September 2021 thru September 2022
- Specific tasks include:
  - Complete the development of a preliminary mudspot/soft spot risk assessment model
  - Make hardware and software improvements to the *MRail* vertical track deflection measurement system (VTDMS)

Task Goal - System Improvements
Autonomous and DOTX218 *MRail* systems

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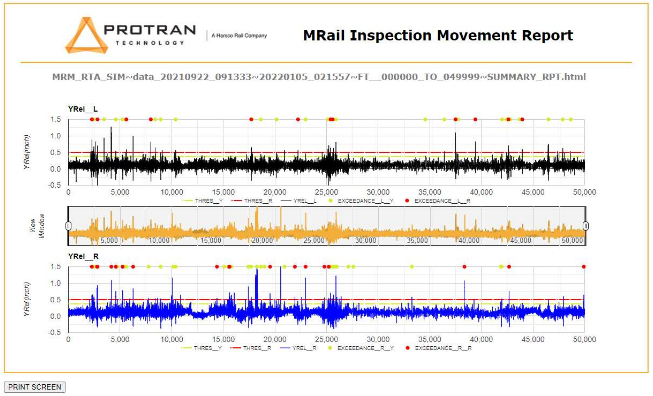
- Software
  - System software is being updated to create more “real-time” output
    - Current output is not highly useable without post processing
    - Want an end user to get useful info right out of the system
    - New output to include:
      - Foot-by-foot strip chart reports
      - Exceedance reports
      - Mudspot/soft spot risk report
  - Update DOTX218 software to latest release
    - Incorporates quality of life changes made to autonomous system software
    - Software testing is required due to system differences

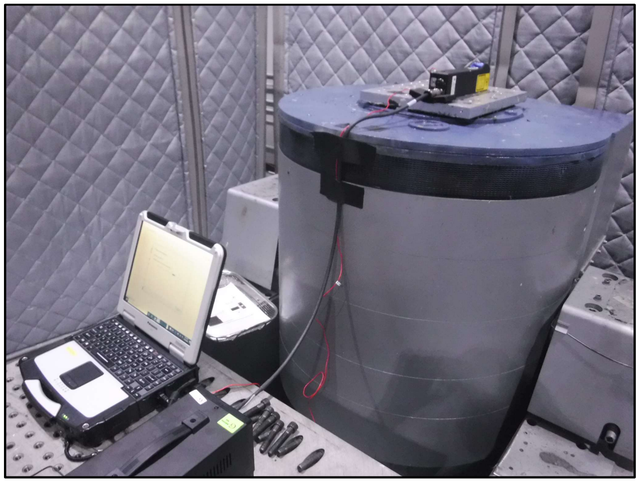


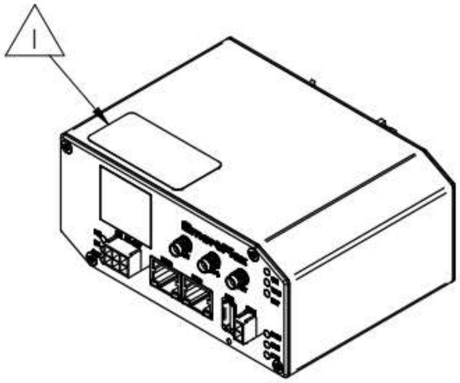
Prototype system level strip chart report

Goal is to move the current prototype system to a production level product

Task Goal - System Improvements
Autonomous and DOTX218 *MRail* systems

- Hardware
  - Integrate new cell modems into *MRail* systems (DOTX218 and autonomous)
  - Investigate new standard sensor head
    - New sensor head candidate selected
    - Completed bogie mounted shock testing
      - Sensor was certified without visual damage and core functionality intact
    - Review plan for implementation to include design overhaul





Goal is to move the current prototype system to a production level product

Task Goal - Risk Assessment Model

Demonstrate that mudspot/soft spot risk assessment evaluation is feasible, practical, and low cost

- Utilize existing technology to measure rail deflection along track
  - Done using *MRail* vertical track deflection measurement system
- Develop risk model for mudspots using vertical track defection data
- Test developed model over an extended application
- Review model results with partner railroad to improve usability and refine results
  - Genesee & Wyoming Railroad (GWRR)
- Deliver final report to FRA describing results

Why Risk Assessment is Important

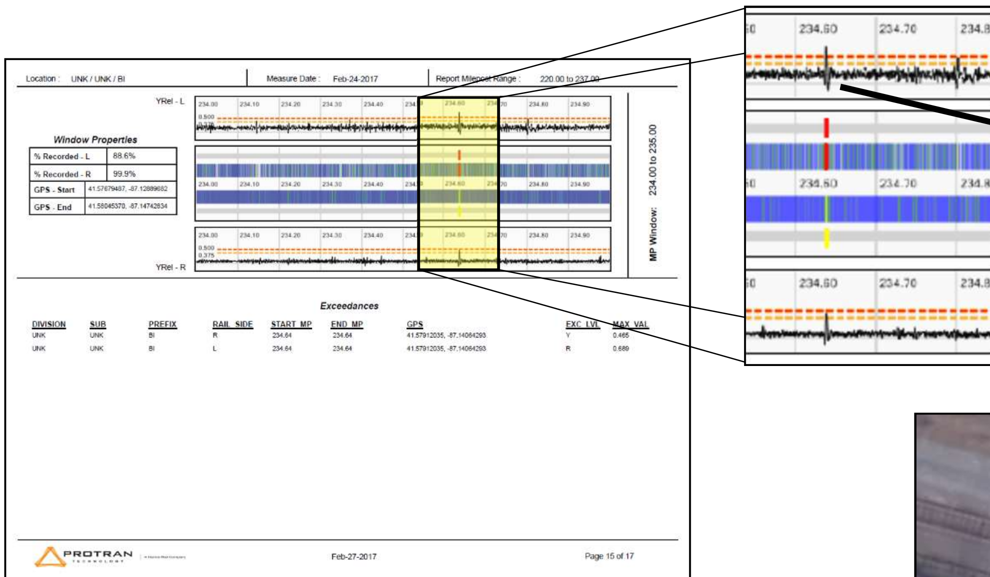
- Mudspots are a common occurrence on US track
- Mudspots can increase in severity over time
  - Water + cyclical axle loading
  - Track support weakens
- Maintenance may not be directed to the “worst” actor

Prioritizing maintenance is paramount to decreasing possible rail breaks and derailments caused by soft spots in track

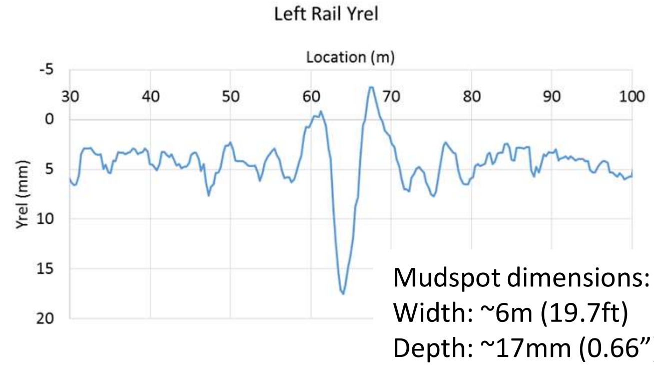
Preliminary Risk Model

Mudspot Example

- Mudspots were first identified using deflection reports and Google Maps for visual verification
  - No field evaluation conducted



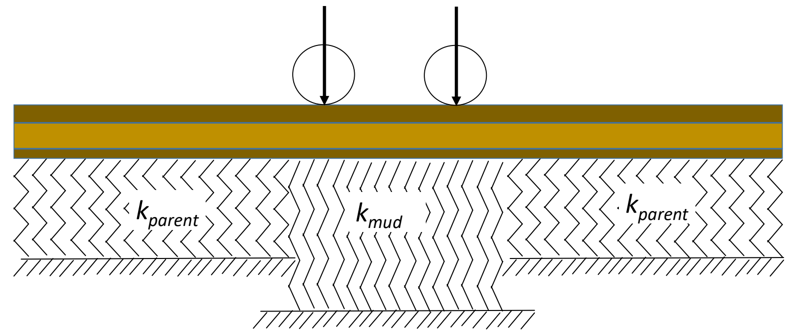
Early version of strip chart report



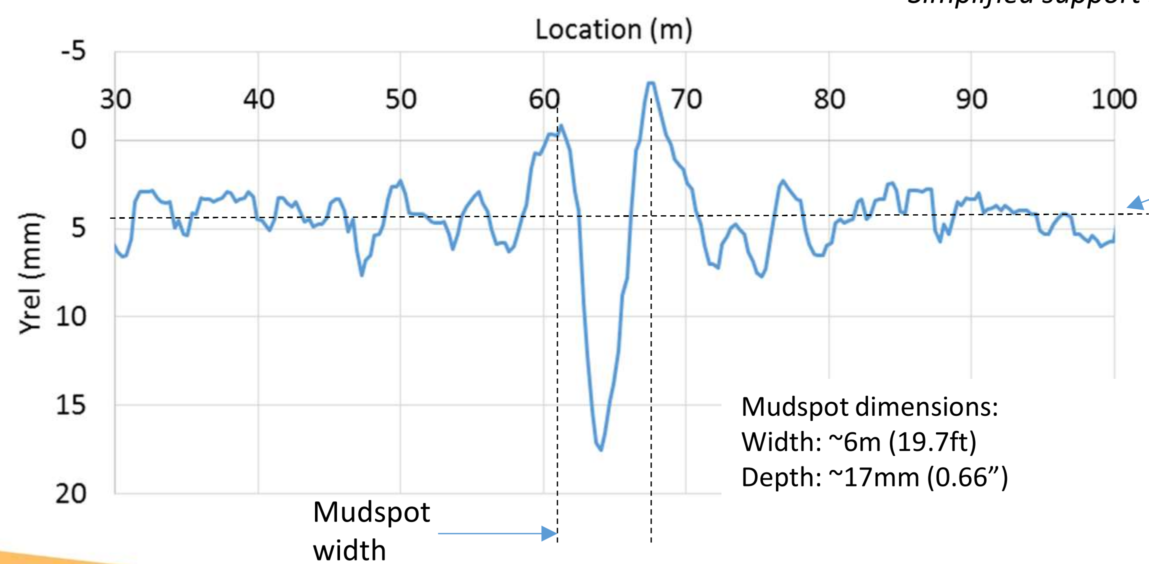
Preliminary Risk Model

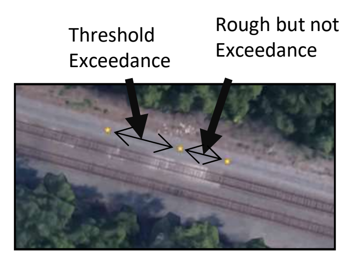
BoEF Mudspot Model

- Mudspot modeled as region of low stiffness flanked by identical higher stiffness parent track
  - Low stiffness zone width is width from the peaks of the lift regions



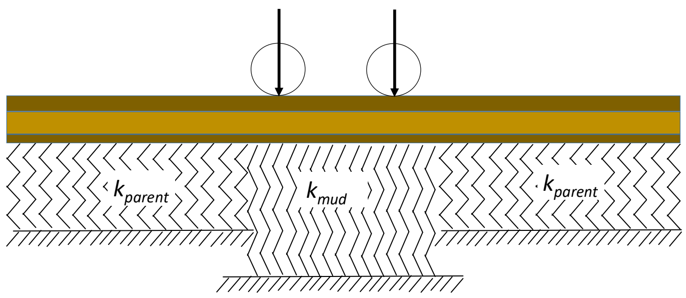
Simplified support structure of mudspot



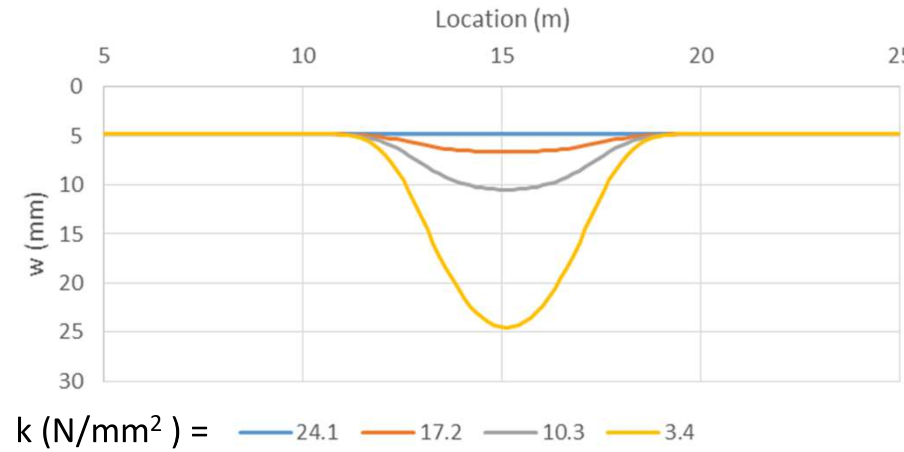


Preliminary Risk Model

BoEF Mudspot Model



Simplified support structure of mudspot



Max deflection under two wheel BoEF superposition

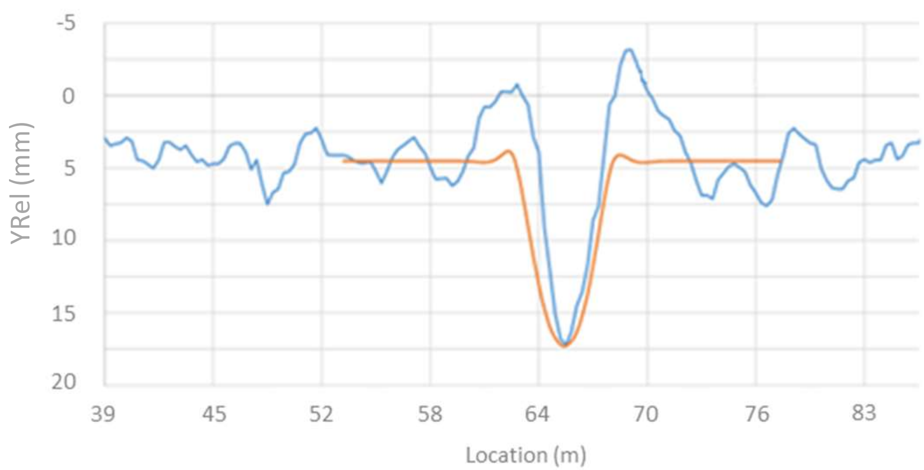
- BoEF was utilized to determine maximum deflection from wheelset
  - Modelled as series of homogeneous ordinary differential equations with boundary condition, matching conditions, and regularity conditions (for an infinite beam)*
  - k_{parent} = 24.1 N/mm^2
    - 24.1 produces a mean deflection of about 4.7mm (0.185")
  - k_{mud} varied

*Zarembski, A. M., Palese, Joseph, J. W., Katz, Leonid, "Implementation of a Dynamic Rail-Highway Grade Crossing Transition:, Transportation Research Board Annual Meeting, Washington, D.C., January 1999

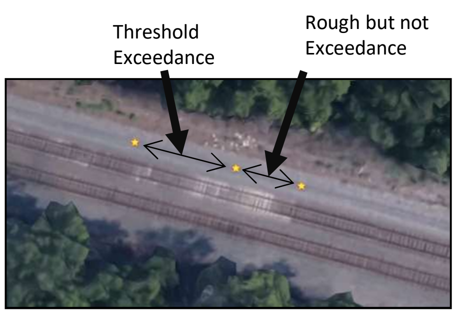
Preliminary Risk Model

BoEF vs. YRel

- BoEF data was converted to YRel and overlaid with example mudspot YRel
  - Parent track stiffness of 24.1 N/mm^2
  - Mudspot
    - length/width 6m (19.7ft)
    - Stiffness 3.4 N/mm^2
- Peak deflection matches well
- Deviation in lift regions not seen in BoEF due to rail fixation assumption



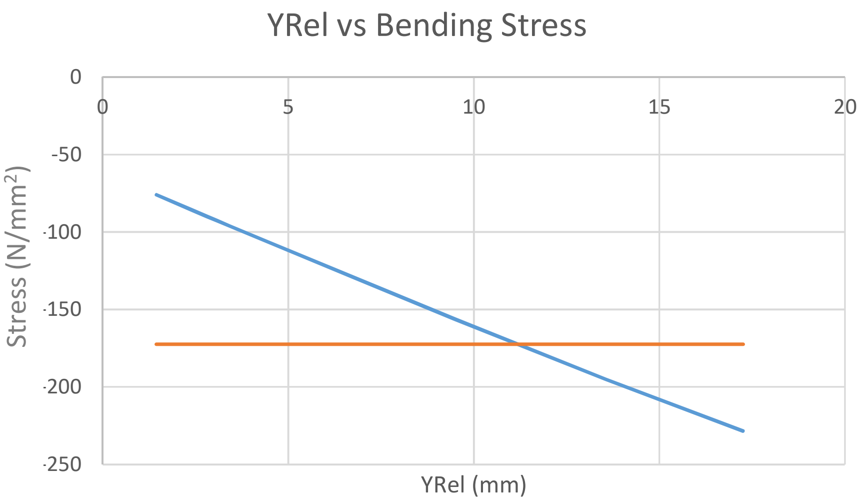
BoEF YRel (Orange) overlaid with measured YRel (Blue)



Preliminary Risk Model

Risk guidelines

- Rail base bending stress was selected as the basis for the risk model
- With that basis selected:
  - 170 N/mm^2 set as the conservative allowable bending stress in rail
    - AREMA allowable stress recommendation
  - YRel > 12mm (0.47”) exceeds 170 N/mm^2 limit

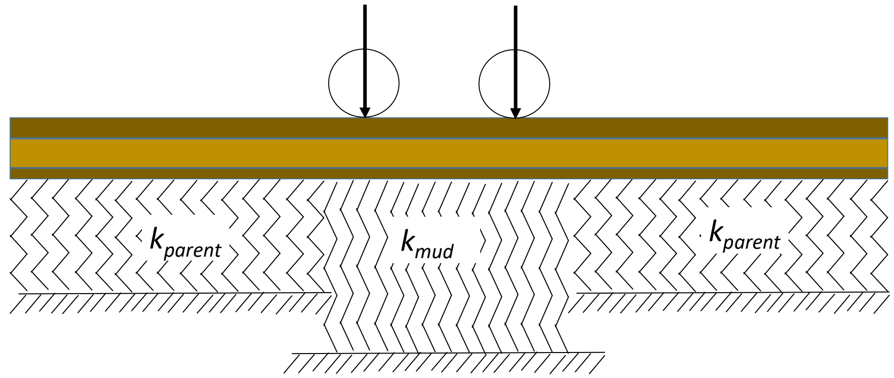


YRel bending stress (Blue)
Bending stress limit (Orange)

Preliminary Risk Model

Risk guidelines

- A deflection basin is created from the passing axle
  - The basin will have some radius of curvature (R)
- R is directly related to the max deflection (YRel) and the width of deflection basin
- Based on bending stress:
  - Larger R → Lower stress
  - Smaller R → Higher stress
  - R < 100m (328ft) exceeds the 170 N/mm^2 bending stress threshold



Sub-structure stiffness transition for parent track to mudspot

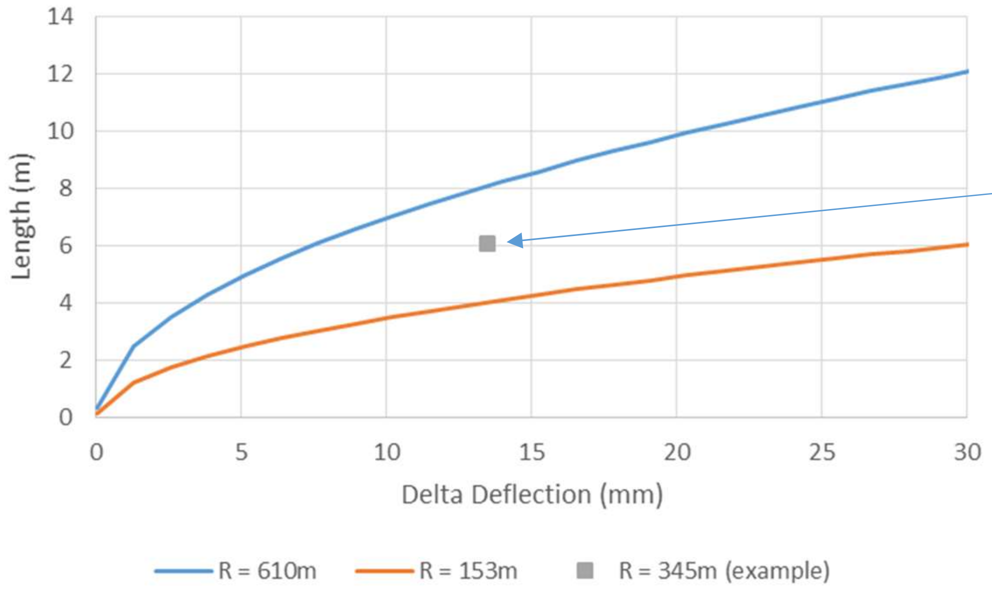
$$R = \frac{L * L}{8(y_0 - y_{max})} + \frac{y_0 - y_{max}}{2}$$

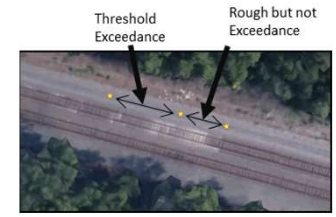
Where

R = Radius of curvature of the *YRel* path
L = Length of *YRel* map
y_0 = Mean value of *YRel* in parent track
y_{max} = Max value of *YRel* in mud spot

Preliminary Risk Model

Risk Guidelines





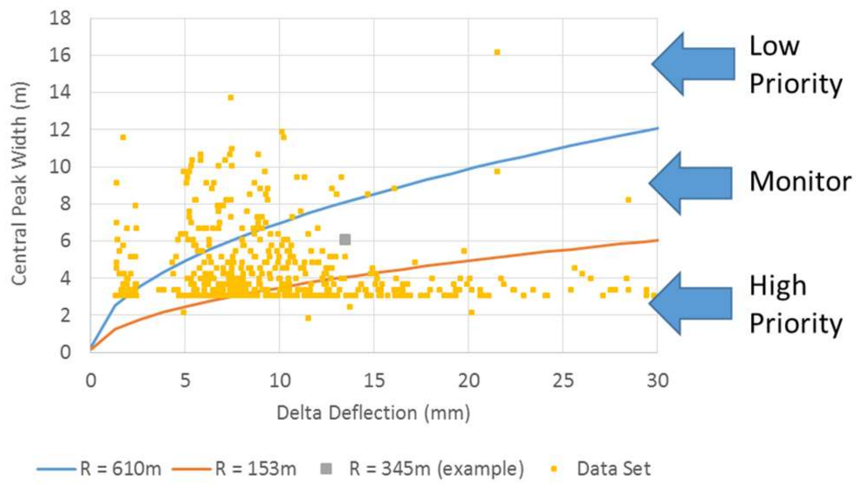
Radius of curvature as a function of central peak length (width) and deviation from mean deflection

- Initial thresholds set at R = 610m (2000ft) and R=153m (500ft)
  - R = 100m (328ft) produces bending stress exceedance
  - Currently conservative
- Example mudspot falls in the middle of two thresholds

Preliminary Risk Model

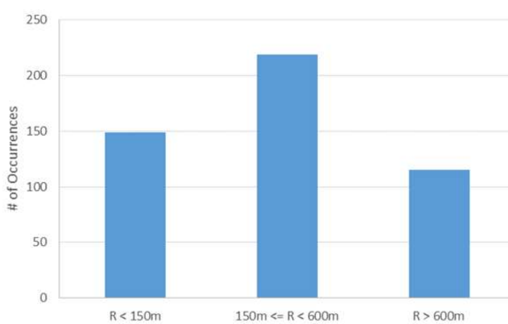
Risk guidelines

- Initial thresholds set at R = 610m (2000ft) and R=153m (500ft)
  - R = 100m (328ft) produces bending stress exceedance
  - Currently conservative
- Example of 850 km of track shown below (497 signatures identified)
  - *MRail* data from another project partner



Signal radius of curvature values

Radius of Curvature (m)	Risk Level
R > 600m	Low
150m < R < 600m	Monitor
R < 150m	High



Signal distribution in risk windows

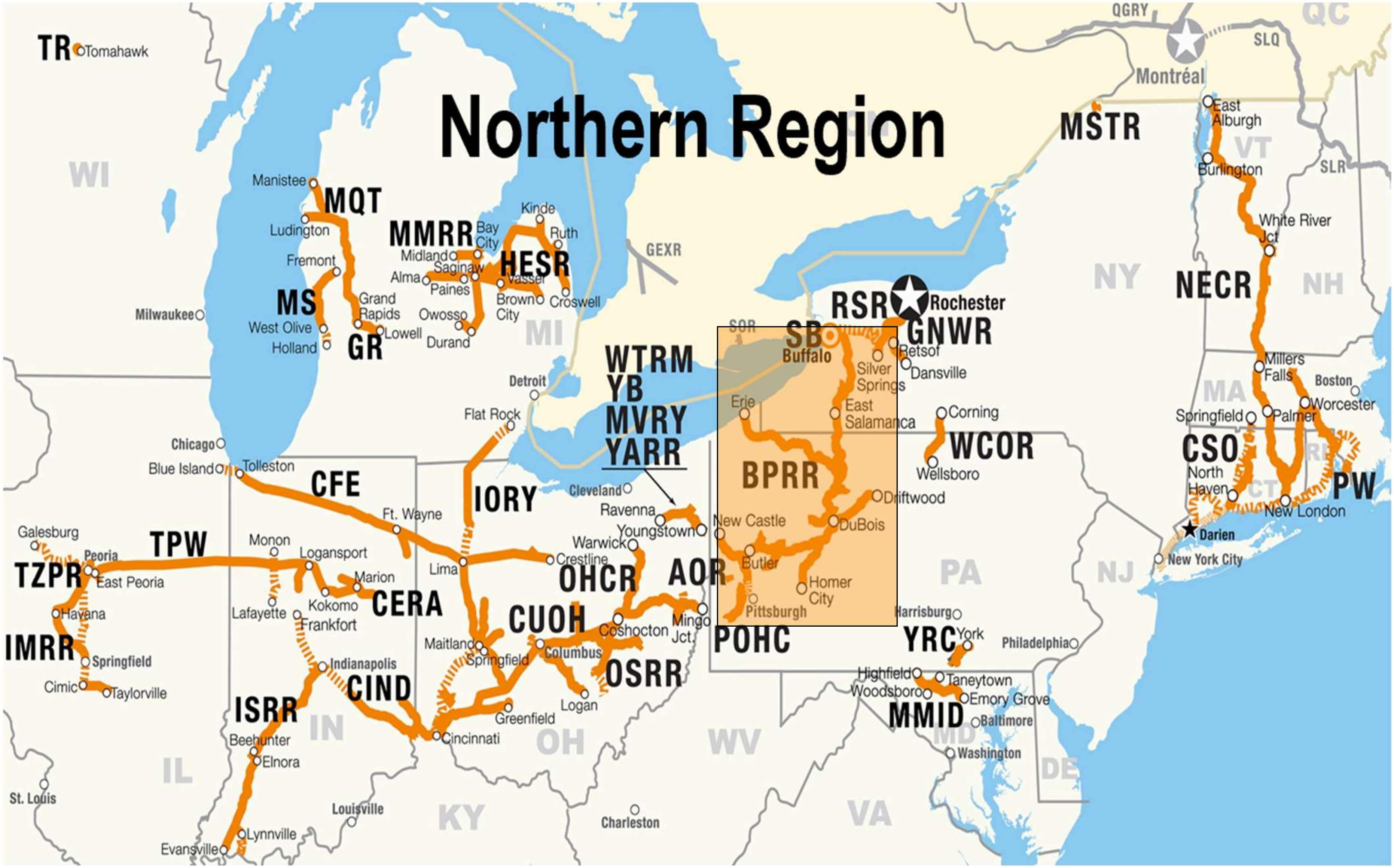
Real World Application

Mudspot/Soft Spot Risk Assessment Model

Genesee & Wyoming Railroads

FRA – HARSCO - Buffalo & Pittsburgh Railroad

Northern Region Genesee & Wyoming Railroad

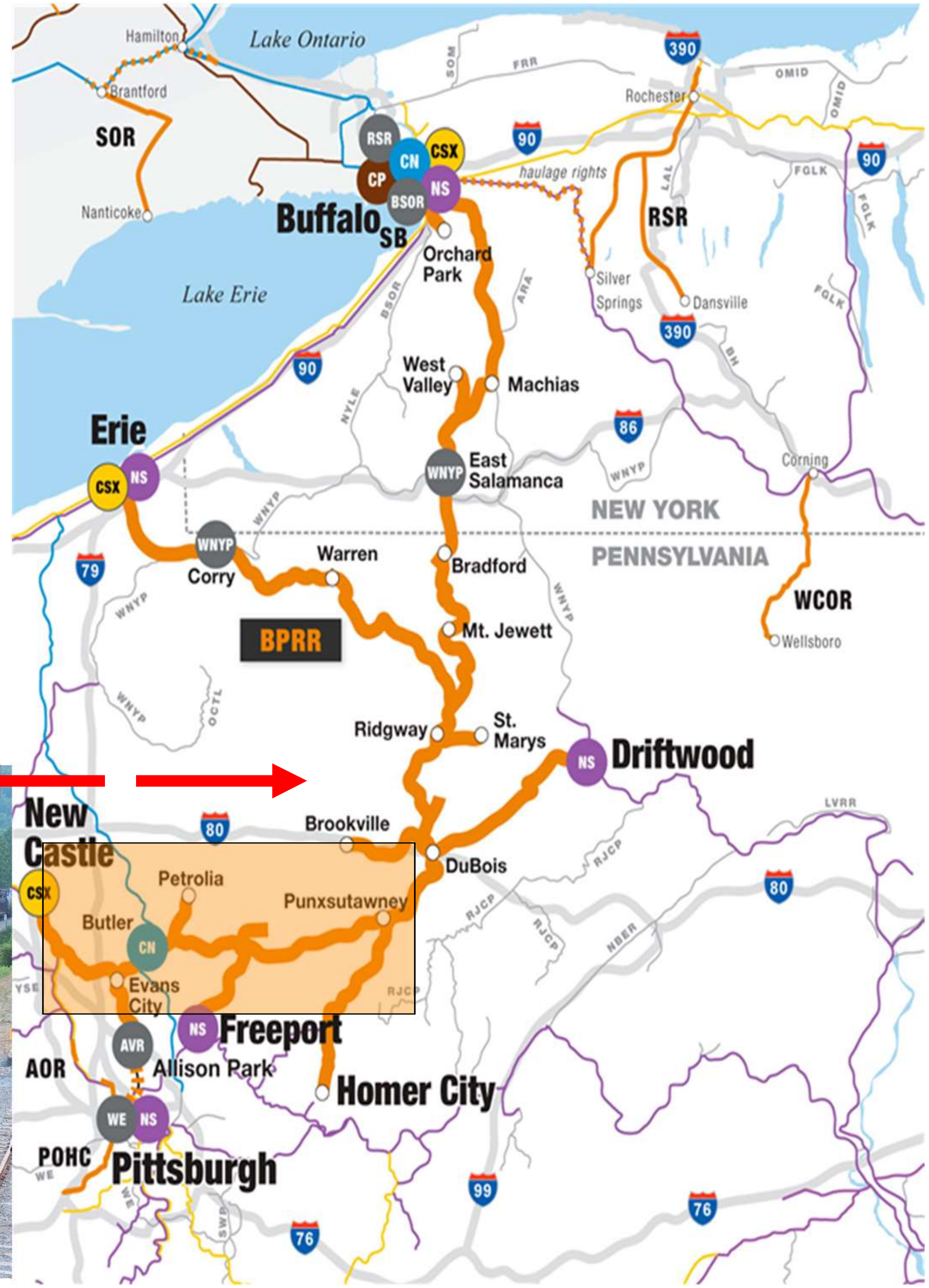


MRail System

Buffalo & Pittsburgh Railroad

The MRail system mounted to the RMS0001 Railcar has been traversing the Southern portion of the BPRR MP 226 and MP 303 Mainline Subdivision. Heavy grade and high curvature. Class II track (Punxsutawney to Edineau)

GWRR partnered with FRA and HARSCO in 2019 to operate the MRail system, working in conjunction with our track inspectors, geometry testing and continual overlay and data comparison with MRail data, field verification and geometry overlay.



MRail System

Buffalo & Pittsburgh Railroad

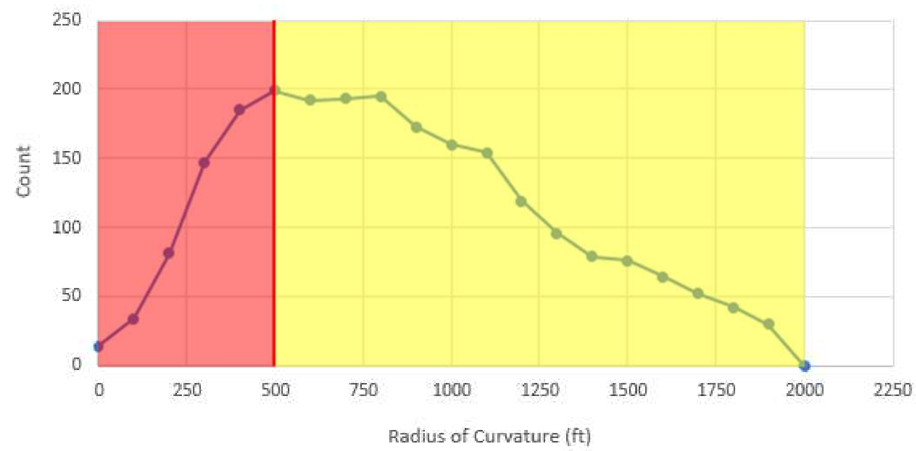
The Buffalo & Pittsburgh Railroad has approximately 20 MGT's annually with heavy grades and high curvature. Pusher operations are frequent for the heavy tonnage coal and other commodities. GWRR conducts two geometry test per year in addition to rail flaw contractors testing four times annually. Extreme weather variances and storm activity create challenging work to maintain the railroad.

MRail System Output

Single inspection movement summary

- A single inspection run from Butler, PA to Punxsutawney, PA was used to guide this process
  - ~50 miles of track
- 2285 location flagged
  - Left / right independent
  - 461 red
- Highest concentration from 500 to 800 ft RoC

Distribution of flagged soft spots (red and yellow)



Track Inspection

Comparison of *MRail* output to actual track condition

- To further refine and improve the model, system output was compared to actual track conditions
  - Goal was to observe mudspots and compare *MRail* output/ranking to visual severity
- Prior to arrival, several track locations were selected for review
  - Sites selected based on:
    - Number of issues flagged
      - Lots of risk locations
      - Clustering of problems
    - Proximity to the starting location
    - Proximity to interesting track features

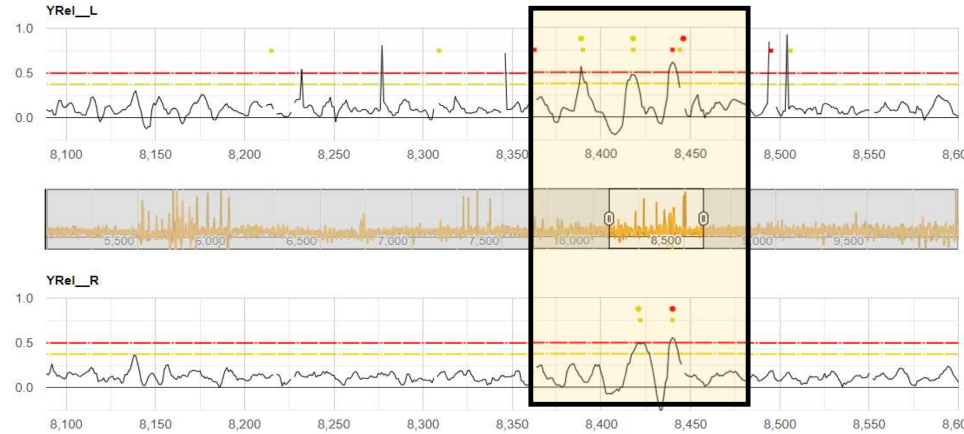
Inspection Site 1

Pre-arrival assessment

PROTRAN TECHNOLOGY
A Harsco Rail Company

General Site Description:
Approach to short bridge

Google Maps image of location



MRail system strip chart output

Table of local issues (exceedances and RoC risk)

MP (est)	MP (adj)	Len (ft)	Yrel_MAX (inch)	Level	Side	RoC (ft)
284 - 507	283 + 4773	9	0.1555373	Y	L	-1660.785
284 - 601	283 + 4679	12	0.1601271	Y	L	-1753.842
284 - 655	283 + 4625	18	2.419162	R	L	-203.1317
284 - 681	283 + 4599	3	0.5646151	Y	L	
284 - 682	283 + 4598	25	0.4393564	Y	L	-1871.68
284 - 710	283 + 4570	19	0.4751524	Y	L	-1041.688
284 - 710	283 + 4570	5	0.4751524	Y	L	
284 - 713	283 + 4567	9	0.4983154	Y	R	
284 - 714	283 + 4566	28	0.4821355	Y	R	-1826.113
284 - 732	283 + 4548	25	0.5534053	Y	R	-1387.559
284 - 732	283 + 4548	10	0.6116211	R	L	-360.8336
284 - 732	283 + 4548	5	0.5534053	R	R	
284 - 736	283 + 4544	6	0.3258378	Y	L	-591.9769
284 - 738	283 + 4542	8	1.662649	R	L	
284 - 787	283 + 4493	12	0.5087475	R	L	-468.3425
284 - 798	283 + 4482	6	0.1262168	Y	L	-1145.981

Inspection Site 1

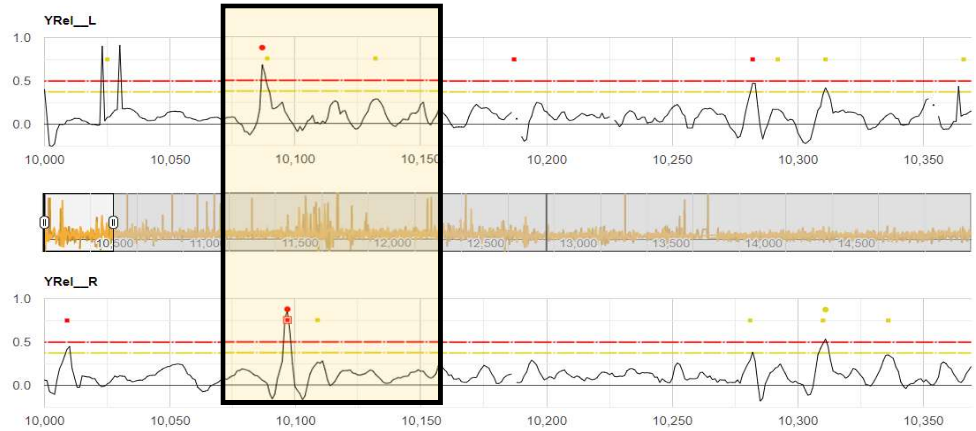
On track assessment – key findings

Item	Comment
Site Description	Approach to a short bridge
Ballast fouling present	NO
Ballast fouling level (0 – 3)	0
Issues observed	YES Lifted rail Bridge cap indenting

Inspection Site 2

Pre-arrival assessment

<u>General Site Description:</u>
Plainline track



MRail system strip chart output

Google Maps image of location

Table of local issues (exceedances and RoC risk)

MP (est)	MP (adj)	Len (ft)	Yrel_MAX (inch)	Level	Side	RoC (ft)
284 - 2379	283 + 2901	2	0.6793898	R	L	
284 - 2381	283 + 2899	20	0.4387362	Y	L	-1155.121
284 - 2389	283 + 2891	12	0.8567687	R	R	-226.0637
284 - 2389	283 + 2891	2	0.8567687	R	R	
284 - 2401	283 + 2879	13	0.2666224	Y	R	-828.9047
284 - 2424	283 + 2856	16	0.2824769	Y	L	-1163.354

Inspection Site 2

On track assessment – key findings

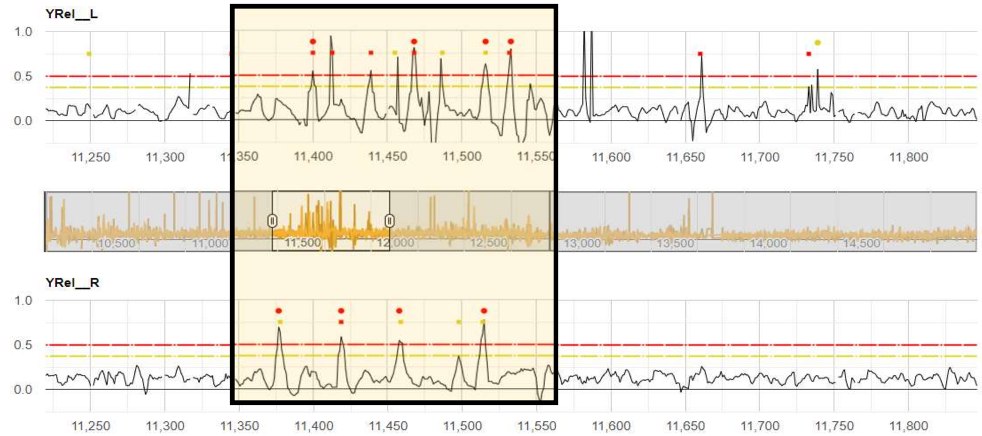
Item	Comment
Site Description	Plainline track
Ballast fouling present	YES
Ballast fouling level (0 – 3)	1
Issues observed	YES Mud

Inspection Site 3

Pre-arrival assessment

<u>General Site Description:</u>
Trailing approach to turnout

Google Maps image of location



MRail system strip chart output

Table of local issues (exceedances and RoC risk)

MP (est)	MP (adj)	Len (ft)	Yrel_MAX (inch)	Level	Side	RoC (ft)
284 - 3670	283 + 1610	16	0.641485	Y	R	-563.116
284 - 3692	283 + 1588	12	0.5453782	R	L	-411.9353
284 - 3692	283 + 1588	2	0.5453782	R	L	
284 - 3705	283 + 1575	10	0.8031763	R	L	-212.9111
284 - 3711	283 + 1569	13	0.5852774	R	R	-424.3726
284 - 3711	283 + 1569	4	0.5852774	R	R	
284 - 3731	283 + 1549	14	0.5544594	R	L	-475.1332
284 - 3747	283 + 1533	6	0.09850004	Y	L	-993.8604
284 - 3750	283 + 1530	3	0.5456561	R	R	
284 - 3751	283 + 1529	20	0.5208839	Y	R	-1337.437
284 - 3760	283 + 1520	15	0.8072582	R	L	-393.266
284 - 3760	283 + 1520	2	0.8072582	R	L	

Inspection Site 3

On track assessment – key findings

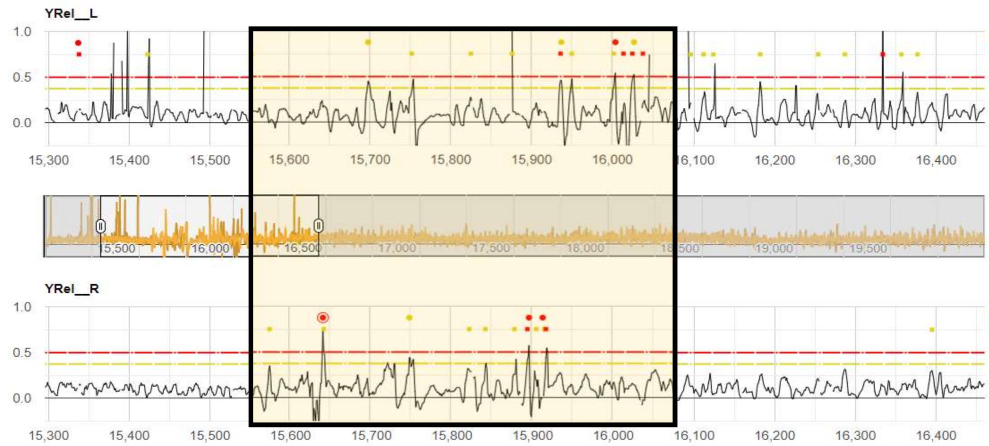
Item	Comment
Site Description	Trailing approach to turnout
Ballast fouling present	NO
Ballast fouling level (0 – 3)	0
Issues observed	YES Broken ties

Inspection Site 4

Pre-arrival assessment

General Site Description:

Turnout/Grade Crossing/Turnout



MRail system strip chart output

Google Maps image of location

Table of local issues (exceedances and RoC risk)

MP (est)	MP (adj)	Len (ft)	Yrel_MAX (inch)	Level	Side	RoC (ft)
283 - 2922	282 + 2358	3	0.727802	R	R	
283 - 2923	282 + 2357	13	0.5128037	Y	R	-588.7562
283 - 2978	282 + 2302	3	0.4507198	Y	L	
283 - 3029	282 + 2251	5	0.44254	Y	R	
283 - 3032	282 + 2248	13	0.3509724	Y	L	-696.4449
283 - 3103	282 + 2177	19	0.3054286	Y	R	-1386.629
283 - 3105	282 + 2175	18	0.2735868	Y	L	-1864.791
283 - 3123	282 + 2157	18	0.3501892	Y	R	-1160.642
283 - 3156	282 + 2124	19	1.0668	Y	L	-530.638
283 - 3159	282 + 2121	16	0.2562554	Y	R	-1311.628
283 - 3175	282 + 2105	12	0.4104158	R	R	-445.8417
283 - 3177	282 + 2103	2	0.5716084	R	R	
283 - 3186	282 + 2094	10	0.1942624	Y	R	-594.6988
283 - 3194	282 + 2086	6	1.710455	R	R	
283 - 3196	282 + 2084	6	0.1178724	Y	R	-1749.812
283 - 3198	282 + 2082	6	0.4379198	R	R	-207.8946
283 - 3216	282 + 2064	12	0.4581042	R	L	-365.2704
283 - 3217	282 + 2063	3	0.4598147	Y	L	
283 - 3230	282 + 2050	16	0.4768628	Y	L	-612.3022
283 - 3282	282 + 1998	17	0.3999821	Y	L	-800.2231
283 - 3284	282 + 1996	2	0.5403442	R	L	
283 - 3294	282 + 1986	11	0.1770044	R	L	-419.8614
283 - 3305	282 + 1975	13	0.4783768	R	L	-378.1807
283 - 3307	282 + 1973	3	0.5246458	Y	L	
283 - 3318	282 + 1962	7	0.204726	R	L	-487.959

Inspection Site 4

On track assessment – key findings

- No observable issues photographed
- Lots of special track work
- Informed that grade crossing "hits hard"
  - May explain some of the issues found in the area

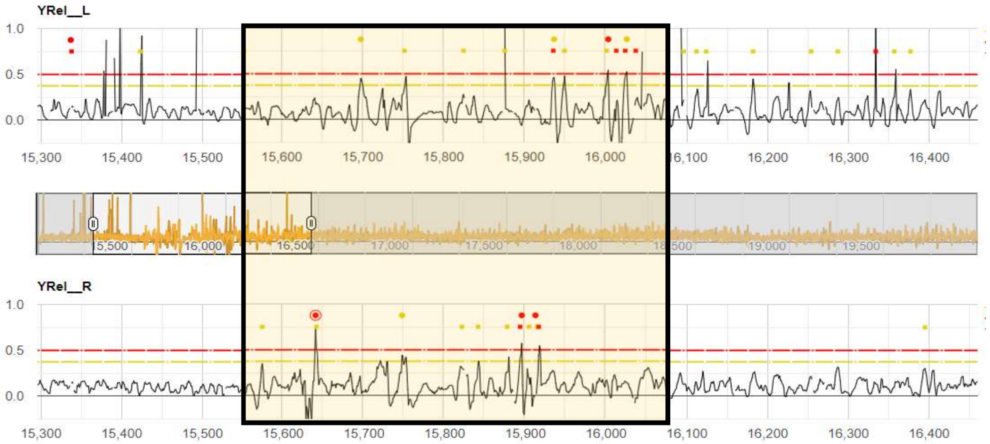
Item	Comment
Site Description	Turnout/Crossing/Turnout
Ballast fouling present	NO
Ballast fouling level (0 – 3)	0
Issues observed	NO

Inspection Site 5

Pre-arrival assessment

General Site Description:
Area around grade crossing with culvert

Google Maps image of location



MRail system strip chart output

Table of local issues (exceedances and RoC risk)

MP (est)	MP (adj)	Len (ft)	Yrel_MAX (inch)	Level	Side	RoC (ft)
281 - 716	280 + 4564	16	0.6186907	Y	L	-629.209
281 - 717	280 + 4563	3	0.705357	R	L	
281 - 738	280 + 4542	6	0.4955752	Y	R	
281 - 756	280 + 4524	15	1.097288	R	L	-261.4592
281 - 756	280 + 4524	7	1.097288	R	L	
281 - 808	280 + 4472	16	0.4340871	Y	L	-920.9702
281 - 808	280 + 4472	2	0.4340871	Y	L	

MP (est)	MP (adj)	Len (ft)	Yrel_MAX (inch)	Level	Side	RoC (ft)
281 - 1623	280 + 3657	10	0.4264315	R	R	-438.5808
281 - 1625	280 + 3655	18	0.3739549	Y	L	-981.973
281 - 1641	280 + 3639	16	0.4384249	Y	R	-641.3497
281 - 1642	280 + 3638	3	0.5670416	Y	R	
281 - 1643	280 + 3637	18	0.5208848	Y	L	-899.166
281 - 1644	280 + 3636	3	0.6352813	R	L	

Inspection Site 5

On track assessment – key findings



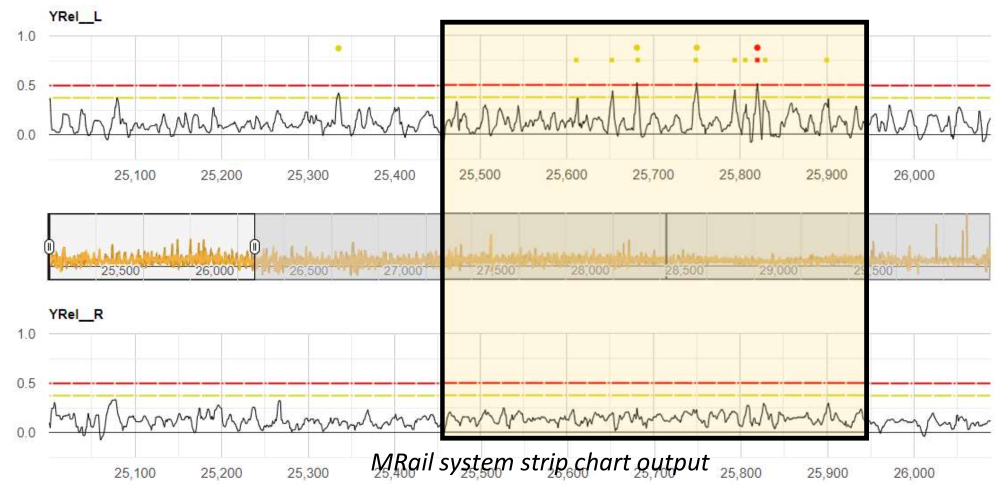


Item	Comment
Site Description	Grade cross + culvert
Ballast fouling present	YES
Ballast fouling level (0 – 3)	2
Issues observed	YES Mud Mud pumping Tie plate cutting into tie

Inspection Site 6

Pre-arrival assessment

General Site Description:
Plainline track in curve



MRail system strip chart output

Google Maps image of location

Table of local issues (exceedances and RoC risk)

MP (est)	MP (adj)	Len (ft)	Yrel_MAX (inch)	Level	Side	RoC (ft)
281 - 2605	280 + 2675	20	0.4511905	Y	L	-1494.728
281 - 2617	280 + 2663	12	0.2216085	Y	L	-908.7101
281 - 2631	280 + 2649	11	0.5129624	R	L	-344.3403
281 - 2631	280 + 2649	2	0.5129624	R	L	
281 - 2640	280 + 2640	14	0.3325807	Y	L	-944.0149
281 - 2711	280 + 2569	17	0.3004133	Y	L	-1708.004

Inspection Site 6

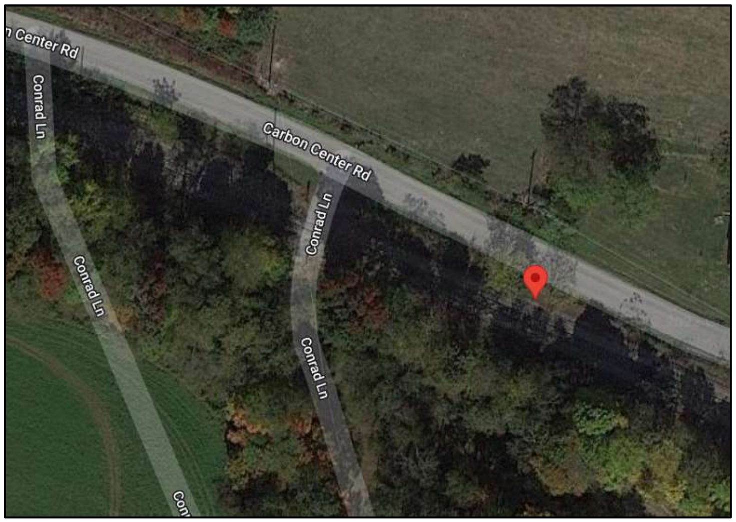
On track assessment – key findings

Item	Comment
Site Description	Plainline in curve
Ballast fouling present	YES
Ballast fouling level (0 – 3)	1
Issues observed	YES Mud pumping Only on high side

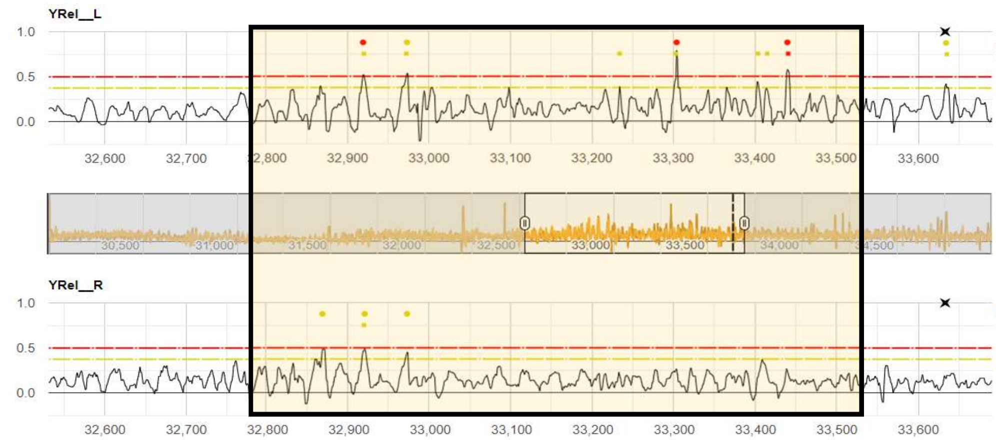
Inspection Site 7

Pre-arrival assessment

General Site Description:
Around grade crossing



Google Maps image of location



MRail system strip chart output

Table of local issues (exceedances and RoC risk)

MP (est)	MP (adj)	Len (ft)	Yrel_MAX (inch)	Level	Side	RoC (ft)
280 - 4885	279 + 395	14	0.3834665	Y	L	-683.9345
280 - 4954	279 + 326	22	0.4686331	Y	L	-1562.908
280 - 4955	279 + 325	4	0.7853978	R	L	
280 - 5055	279 + 225	14	0.4323488	Y	L	-739.9408
280 - 5066	279 + 214	14	0.3568072	Y	L	-827.5823
280 - 5091	279 + 189	4	0.573788	R	L	
280 - 5092	279 + 188	11	0.5629395	R	L	-368.6211
279 - 0	279 + 0	13	0.3766525	Y	L	-853.6743

Inspection Site 7

On track assessment – key findings

Item	Comment
Site Description	Around grade crossing
Ballast fouling present	YES
Ballast fouling level (0 – 3)	3
Issues observed	YES Heavy presence of mud Standing water

Maintenance Prioritization

- Shown are each site ranked by various parameters
  - Smallest radius of curvature (RoC)
  - Highest maximum exceedance measurement
  - By inspector recommendation from observing the area
  - Highlight → mud present at site

Sites with ballast fouling

Image of site 2

Image of site 5

Image of site 6

Image of site 7

Maintenance Prioritization

All sites

	MRail System Output		
	By Worst RoC	**By Worst Exceedance**	**Inspector 1**
Site Ranking	1	4	7
	4	1	5
	3	5	1
	2	2	2
	5	3	6
	6	7	4
	7	6	3

Mud sites

	MRail System Output		
	By Worst RoC	**By Worst Exceedance**	**Inspector 1**
Site Ranking	2	5	7
	5	2	5
	6	7	2
	7	6	6

- Interesting findings
  - Site 7 (mud – heavy): *MRail* output gives low priority but visual is high
  - Site 2 (mud – lite): Middle for all ranking methods
  - Site 1 (lifted rail + bridge): Top 50% for all rankings
  - Site 6 (mud – lite): Bottom 50% for all rankings

Sites with ballast fouling

Image of site 2

Image of site 5

Image of site 6

Image of site 7

Maintenance Prioritization

Inspection sites with visual mud only

	MRail System Output		
	By Worst RoC	By Worst Exceedance	Inspector 1
Site Ranking	2	5	7
	5	2	5
	6	7	2
	7	6	6

- What does this mean?
  - Exactly what the model was meant to do
    - Results appear to be counter intuitive vs. visual
  - Further validation should be done
    - Track side observations / measurements
    - Stop a train at the site for measurements
    - Compare and contrast the site configurations
      - Location/drainage
      - Joints vs CWR
      - Special track work

Sites with ballast fouling

Image of site 2

Image of site 5

Image of site 6

Image of site 7

Maintenance Prioritization

Comparison of all sites

	MRail System Output		
	By Worst RoC	By Worst Exceedance	Inspector 1
Site Ranking	1	4	7
	4	1	5
	3	5	1
	2	2	2
	5	3	6
	6	7	4
	7	6	3

Image of site 1

- Further validation should be done
  - Track side observations
  - Stop a train at the site for measurements
  - Focus on sites without mud
    - Why was deflection so high?
      - How were the joints in the area?
    - Do the rough tracks actually have significant deflection or is the impact causing sensor position change?

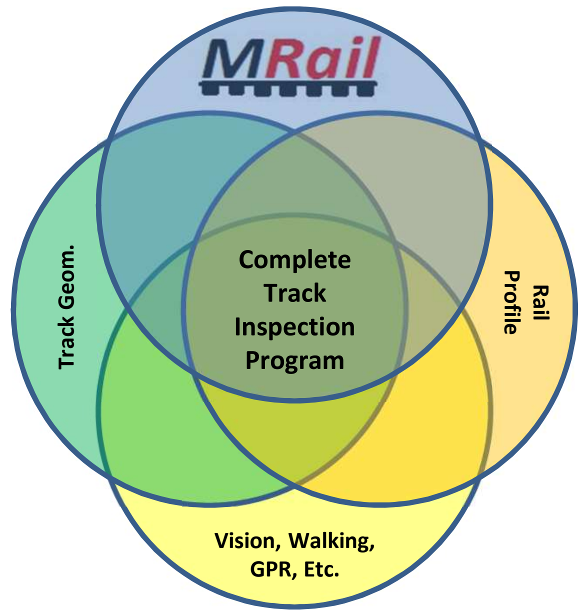
How GWRR is Using *MRail* Data

Using the MRail system output for making decisions

Discussion

How Does the End User Utilize the Data

- *MRail* provides additional information that will assist in planning track and structure maintenance and capital work
- Complimenting existing track/infrastructure testing and inspections
  - Track Geometry, Rail Wear, Bridge Inspections, AURORA, RFD, etc.
- Strong benefits towards focus on spending funds in the right locations
  - Use data to understand mud fouled / soft areas that are problematic as opposed to not
  - Enable better prioritization of work programs.
    - Example: mud fouled track with good track geometry and low deflection would be prioritized lower



What GWRR has done so far

- Use data to prioritize spot surfacing
- Correlation of how fouled ballast is affecting track geometry

Going Forward

Improvements Going Forward

- More site observations and feedback needed
  - Better understanding around special track work
    - How real are the deflections being reported?
  - Comparisons with other inspection data
  - Continued monitoring
  - Cross-reference with any rail issues that arise
- Improved location association
- Gather more information on “hard hitting” areas
- RoC model refinement
- Additional report outputs
  - Top X issues
  - Method for evaluating clusters of issues
  - Methods for overlaying with alternate data
    - Example: track geometry

PROTRAN TECHNOLOGY

GENESEE G&W WYOMING

U.S. Department of Transportation
Federal Railroad Administration

Thank you!